Journal of the American Mosquito Control Association, 10(3):385–389, 1994

LABORATORY EVALUATION OF FENITROTHION MICROCAPSULES AS A NEW RESIDUAL SPRAYING FORMULATION FOR MOSQUITO CONTROL

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ABSTRACT. Physicochemical and insecticidal properties of fenitrothion microcapsule (MC) as a new residual spraying formulation for mosquito control were studied. The wall staining after treatment with MC at the rate of 1–2 g AI/m² was not noticeable as compared with that of wettable powder (WP). Covering rate with MC on a vertical wall was almost the same as WP and emulsifiable concentrate (EC) when the wall material was absorptive plywood and mud, and was relatively higher than WP and EC when the wall material was nonabsorptive overlaid plywood. Residual efficacy of MC at the rate of 1 g/m² was almost equivalent or superior to that of WP at the rate of 2 g/m². Fenitrothion MC also has had an "airborne" effect, which is sort of a vapor killing effect of insecticides under high vapor pressure. This suggested a difference in mode of action in mosquitoes from that for cockroach control.

INTRODUCTION

Residual spraying of insecticides is still regarded as a major malaria vector control measure. Organochlorine insecticides have been used for residual spraying since the mid-1940s. The use of these chemicals, however, is becoming restricted in some areas for various reasons, of which the most serious is the development of physiological and/or behavioral resistance of mosquitoes to DDT (Taylor 1975, Curtis and Lines 1987, Rozendaal et al. 1989). Lack of irritancy or repellency to organophosphorous (OP) insecticide by mosquitoes will moderate the development of behavioral resistance. Many OP insecticides are sorptive to mud and may need more frequent treatment when compared with DDT (Bruce-Chwatt 1985). Wettable powder (WP) formulations have been widely employed for the enhancement of residual efficacy on absorptive substrata. However, treatment with WP may stain the wall and may be cause for refusal by residents. Microencapsulation of insecticides is thought to be one of the most appropriate ways to solve these problems. In this paper, we report on the physicochemical and insecticidal properties of fenitrothion microcapsule (MC) as a new residual spraying formulation for mosquito control. We also discuss the differences in modes of action of the present MC formulation from those of MCs for cockroach control (Kawada et al. 1990, 1993).

MATERIALS AND METHODS

Microencapsulation procedure: The microcapsules containing 20% fenitrothion (*O, O*-dimethyl *O*-4-nitro-m-tolyl phosphorothioate) were prepared by interfacial polymerization using polyurea as a wall material (Ohtsubo et al. 1987, Tsuda et al. 1987).

Bioassay—confined contact test: Four different kinds of panels (plywood, unglazed pottery, mud [fine textured yellow soil 10 parts, plaster 2 parts, water 10 parts were mixed and dried for more than 7 days at 25°C] and overlaid plywood panels) were cut into square pieces (15 × 15 cm). The microencapsulated and wettable powder formulations of fenitrothion (Sumithion 40WP) were suspended in deionized water and were sprayed onto each panel at the rate of 50 ml/m². After the panels were dried for 24 h at 25°C, 10 adult female mosquitoes, *Culex pipiens pallens* Coq. (Gose strain, which shows normal susceptibility to insecticides), were confined to contact the treated surface for 2 h. The insects were then transferred into a clean plastic cup with 5% sugar solution as a diet, and mortality was observed after 24 h. The panels were stored at 25°C and 60% RH. Residual efficacy was examined in the same manner as described above by using the same panel.

Bioassay—noncontact test: The microencapsulated and wettable powder of fenitrothion were suspended with deionized water and were sprayed onto plywood panels (15 × 15 cm) at the rate of 50 ml/m². After the panels were dried for 24 h at 25°C, a cube box was made in which one side was treated with insecticide and the other sides and bottom were not treated. Ten adult female *Cx. pipiens pallens* were confined into a small spherical stainless steel cage (4 cm diam) that was hung in the center of the cube box for 2 or 24 h. Five percent sugar solution was provided as food. The top of the box was covered with another clean plywood panel. Mortality was observed after 24 h. The box was maintained under

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Table 1. Residual contact efficacy of fenitrothion microencapsulated and wettable powder against *Culex pipiens pallens* on various surface materials.

Formulation	Dosage (g AI/m²)	Material	% mortality at different weeks after treatment 0	4	12	20	28	36	48
Microencapsulated	2	Plywood	100	100	100	100	100	100	100
		Overlaid	100	100	100	100	100	100	100
		Unglazed	100	100	100	100	96.7	100	96.7
		Mud	100	100	90.0	93.3	83.3	93.3	70.0
	1	Plywood	100	100	100	100	100	96.7	100
		Overlaid	100	100	100	100	100	100	100
		Unglazed	100	100	100	100	93.3	89.7	92.9
		Mud	96.0	90.0	96.7	80.0	30.0	46.7	—
	0.5	Plywood	100	100	100	100	86.7	48.3	40.0
		Overlaid	100	100	100	100	100	100	96.7
		Unglazed	100	100	100	86.7	90.0	73.3	96.7
		Mud	85.0	66.7	60.0	33.3	—	—	—
	0.25	Plywood	100	100	80.0	70.0	66.7	36.7	—
		Overlaid	100	100	100	100	100	69.0	76.7
		Unglazed	100	100	100	80.0	90.0	33.3	—
		Mud	34.0	46.7	30.0	—	—	—	—
Wettable powder	2	Plywood	100	100	100	100	100	100	100
		Overlaid	100	100	100	100	100	100	100
		Unglazed	100	100	100	100	100	100	86.7
		Mud	100	100	53.3	0	—	—	—
	1	Plywood	100	100	100	100	100	100	100
		Overlaid	100	100	100	100	100	100	100
		Unglazed	100	100	100	69.0	[1]	—	—
		Mud	100	0	—	—	—	—	—

[1] Mortality reduced to 23.3% at 24 wk.

the same conditions noted above. Residual efficacy was examined in the same manner as previously described.

Determination of covering rate in vertical wall treatment: Three different kind of panels: plywood, mud, and overlaid plywood panels (15 × 15 cm), were used. The microencapsulated, wettable powder, and emulsifiable concentrate of fenitrothion were suspended or diluted with deionized water and were sprayed horizontally onto each panel at the rate of 50 ml/m². The distance from spray nozzle to the panel was 50

Table 2. Residual noncontact efficacy of fenitrothion microencapsulated and wettable powder against *Culex pipiens pallens.*

Formulation	Dosage (g AI/m²)	Exposure time (h)	% mortality at different weeks after treatment 0	4	9	21	30	40	47
Microencapsulated	2	24	100	100	100	100	100	100	100
		2	100	100	100	100	100	100	93.3
	1	24	100	100	100	100	100	100	100
		2	100	83.3	86.7	100	96.7	96.7	13.3
Wettable powder	2	24	100	100	100	100	100	100	100
		2	100	100	100	100	100	100	93.3
	1	24	100	100	100	100	100	100	100
		2	100	100	86.7	50.0	76.7	80.0	23.3

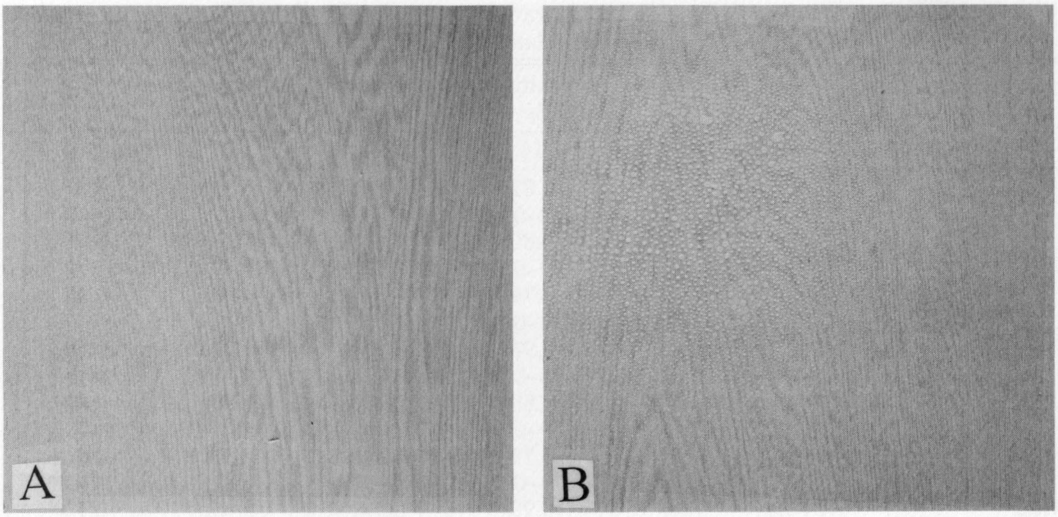

Fig. 1. Surface appearance of overlaid plywood panels after spraying 5 times with a 20% suspension of microcapsules (A) and 20 times with a 40% suspension of wettable powder (B) at the rate of 50 ml/m². The amount of fenitrothion on each panel was calculated to be 2 and 1 g AI/m², respectively.

cm. Panels were dried for 24 h at 25°C in the vertical position. Each panel was immersed in 50 ml of acetone and was sonicated for 10 min for extraction of fenitrothion. The amount of fenitrothion on the panel was analyzed with a gas chromatography equipped with a flame photometric detector under the following conditions; glass column, 1.1 m × 3 mmϕ, packed with 3% XE-60 on Chromosorb W (AW, DMCS) 60–80 mesh; carrier gas, nitrogen; injection temperature, 230°C; column temperature, 170°C.

Determination of stability of fenitrothion on different materials: The same types of panels, insecticide formulations, and application rate as in the previous experiment were used. After storage under the same conditions, the fenitrothion residue was analyzed with gas chromatography as previously described.

RESULTS AND DISCUSSION

Residual efficacy of fenitrothion MC against mosquitoes: Residual efficacy of fenitrothion MC and WP on the different surfaces is shown in Table 1. High mortality was maintained for more than 48 wk with MC and WP sprayed on overlaid plywood panels. Mortality decreased gradually on unglazed pottery and mud surfaces with both formulations. The decrease in mortality was most prominent with the WP treatment on the mud surface (i.e., the effective duration of WP on mud surface was less than 20 wk at 2 g AI/m² and was less than 4 wk at 1 g AI/m²). The MC treatment on a mud surface maintained high mortality (>80%) for more than 20 wk at 1 g AI/m² and for more than 36 wk at 2 g AI/m².

Residual noncontact efficacy of fenitrothion MC and WP on a plywood surface is shown in Table 2. High mortality was maintained for more than 47 wk with both MC and WP when mosquitoes were exposed for 24 h when only one side of the wall was treated. With a 2-h exposure period, mortality decreased gradually and the decline curve was almost the same in both formulations. The effective duration for both formulations.

Table 3. Amount of fenitrothion on the various vertical surfaces after spraying of 3 different formulations.

Material	Formulation	Fenitrothion on a panel (g AI/m²)	
Plywood	MC	0.83	(0.81–0.85)[1]
	WP	0.92	(0.89–0.95)
	EC	0.94	(0.91–0.97)
Overlaid plywood	MC	0.94 a[2]	(0.89–0.99)
	WP	0.58 b	(0.56–0.60)
	EC	0.65 b	(0.62–0.68)
Mud	MC	1.35	(1.31–1.39)
	WP	1.18	(1.13–1.23)
	EC	1.28	(1.21–1.35)

[1] Numbers in parentheses indicate 95% fiducial limits.
[2] Values followed by different letters are significantly different ($P < 0.1$).

Table 4. Stability of fenitrothion on the various surfaces after spraying of 3 different formulations.

Material	Sample	Fenitrothion on a panel at different days after treatment (g AI/m²) 0	15	30	90	180
Plywood	MC	1.01 (0.94–1.08)[2]	0.82 (0.80–0.85)	0.75a[1] (0.67–0.83)	0.52a (0.50–0.53)	0.47a (0.38–0.56)
	WP	1.00 (0.89–1.10)	0.80 (0.79–0.82)	0.63b (0.62–0.65)	0.43b (0.39–0.47)	0.40b (0.39–0.41)
	EC	1.00 (0.95–1.04)	0.79 (0.77–0.80)	0.66 (0.66–0.67)	0.47 (0.46–0.47)	0.42 (0.41–0.42)
Overlaid plywood	MC	0.97 (0.78–1.17)	0.96 (0.93–0.99)	0.95a (0.91–0.99)	0.77a (0.77–0.77)	0.65a (0.58–0.71)
	WP	0.94 (0.91–0.97)	0.80 (0.69–0.90)	0.82 (0.81–0.83)	0.66 (0.58–0.74)	0.43 (0.34–0.52)
	EC	0.99 (0.90–1.08)	0.78 (0.74–0.83)	0.81b (0.78–0.84)	0.62b (0.48–0.77)	0.34b (0.29–0.39)
Mud	MC	0.94 (0.94–0.94)	0.99 (0.97–1.02)	0.94 (0.92–0.96)	0.96a (0.87–1.05)	0.90 (0.73–1.06)
	WP	0.95 (0.92–0.99)	0.95 (0.86–1.03)	0.92 (0.91–0.94)	0.87b (0.85–0.89)	0.83 (0.79–0.88)
	EC	0.97 (0.93–1.01)	0.94 (0.94–0.95)	0.93 (0.89–0.97)	0.89 (0.88–0.89)	0.83 (0.72–0.94)

[1] Values followed by different letters are significantly different ($P < 0.1$).
[2] Numbers in parentheses indicate 95% fiducial limits.

mulations was less than 47 wk at 1 g AI/m² and was more than 47 wk at 2 g AI/m². These results suggest that the active ingredient diffuses through the microcapsule wall and may indicate that fenitrothion MC for mosquito control has a different mode of action from that for cockroach control. No diffusion of active ingredient through the microcapsule wall was detected and mechanical destruction of the microcapsule wall and mastication in the crop after oral ingestion were the main modes of entry in the latter formulation during cockroach studies (Ohtsubo et al. 1987, Tsuda et al. 1987, Kawada et al. 1990).

Covering rate after treatment to the vertical wall: Figure 1 shows the surface of overlaid plywood panels after spraying of MC and WP at the rate of 2 and 1 g AI/m², respectively. The staining of the wall after treatment with MC was not noticeable as compared to that of WP. Table 3 shows the amount of fenitrothion on the various vertical wall surfaces one day after spraying 10 times the suspension of 20% MC, 20 times the suspension of 40% WP, and 25 times the solution of 50% EC of fenitrothion at the rate of 50 ml/m². The amount of fenitrothion on each panel was, therefore, supposed to be 1 g AI/m². The amount of fenitrothion on the mud surface panel for the 3 formulations was higher, but was not statistically significant, than those on the other surface materials. This may have been due to the high absorption ability of the mud surface. The amount of fenitrothion was significantly higher with the MC treatment than the others in the case of spraying on the nonabsorptive overlaid plywood surface ($P < 0.1$).

Stability of fenitrothion on the different surface materials: Stability of fenitrothion on various surface materials is shown in Table 4. A decrease in the amount of fenitrothion was most prominent on the plywood panels (i.e., the residual amount of fenitrothion decreased to *ca.* 50% or less by 90 days after treatment). Fenitrothion was most stable on the mud surfaces. These results are inconsistent with those of the bioassay, which showed that residual activity was lowest on mud surfaces. A large amount of the fenitrothion in the WP or EC formulation might have been absorbed. In contrast, a large portion of the fenitrothion on plywood or overlaid plywood panel was thought to disappear not by degradation but by vaporization because of lower absorption on these surfaces. The residual amount of fenitrothion after 90 days was significantly higher in MC formulations than those of WP or EC formulations on every surface.

Bruce-Chwatt (1985) stated that a residual insecticide should have "high biological activity against the vector species, with a lethal effect at least 3 months after application and without (or minimal) irritant reaction on the mosquito". Although DDT is in current use, it has an irritant effect on mosquitoes and this seems to accelerate the selection of behavioral resistance. Pyrethroid insecticides should not be used for residual spraying for the same reason. Organophosphorous insecticides, such as fenitrothion and malathion, are thought to be good residual insecticides, from this point of view, because they do not have irritancy or repellency to mosquitoes (Kurihara et al. 1985). The effective duration of organophosphorous insecticides, however, has been regarded as only 3–4 months and this makes the cost of application 5 times as expensive as that of DDT. Our results indicate that the lack of residual effectiveness in fenitrothion WP on mud surface is due to high adsorption on mud surfaces. We can reduce the adsorption of fenitrothion to substrates by microencapsulation and reinforce the residual activity, without reducing the "airborne" killing effect, which is a form of vapor killing effect of insecticides with high vapor pressure (Fontaine et al. 1975). It is expected that the effective duration of fenitrothion can be prolonged to more than 6 or more months when used at the rate of 1 g or 2 g AI/m^2.

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